Industry-academia partnerships in STEM: A meta-synthesis of literature and evidence gaps on gender and gender intersectionality

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About the ARC Network

Funded by the National Science Foundation ADVANCE Program, Awards HRD-2121468 and HRD-1740860, the ADVANCE Resource and Coordination (ARC) Network seeks to achieve gender equity for faculty in higher education science, technology, engineering, and mathematics (STEM) disciplines. As the STEM equity brain trust, the ARC Network recognizes the achievements made so far while producing new perspectives, methods and interventions with an intersectional, intentional and inclusive lens. The leading champion in North America to propel the inclusion of women in the field of engineering, the Women in Engineering ProActive Network (WEPAN), serves as the backbone organization of the ARC Network.

About the Virtual Visiting Scholars

The Virtual Visiting Scholars (VVS) program provides a unique opportunity for select scholars across disciplines to pursue research meta-analysis, synthesis, and big data curation on topics crucial to STEM faculty equity. VVS analyze existing research and data, synthesizing different, sometimes competing, perspectives, frameworks, metrics, and outcomes to offer new insights and applications to the broader community.

About the Author

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Executive Summary

Industry-academia collaborations and partnerships have grown in both popularity and frequency over recent decades, despite being an unpopular concept among some academic cultures that strive to uphold free-thought, thought leadership, and academic freedom. Although some academics have embraced and presently engage in industry-academia partnerships, challenges remain in terms of contextualizing gender and gender intersectionality in industry-academia partnerships in STEM to inform equitable policy and practice. This meta-synthesis compiles research to identify, define, and understand present themes at the intersection of gender and gender intersectionality in industry-academia partnerships in STEM.

Research Summary

Research Question

What is the overall state of evidence on gender and gender intersectionality regarding industry-academia partnerships in STEM?

Statement of Research Problem

For several decades, industry-academia partnerships were an unpopular concept among academics who strived to uphold free-thought, thought leadership, and academic freedom from industry.(1) The 21st century tech revolution inspired a cultural change that welcomed industry-academic partnerships, especially upon the realization among new science, technology, engineering, and math (STEM) graduates that tenure-track faculty opportunities in academia are extremely limited. This realization also sparked the need to reimagine the future of career progression and among current STEM faculty in academia. Large research institutions like the National Institute of Health (NIH) have embraced the concept of industry-academia partnerships by creating funding mechanisms along with policies and standards that are meant to mitigate potential harm to science or individuals participating in scientific research due to investigator or institutional financial ties or conflicts of interest.(2,3)

Also, for many years universities have supported faculty in their pursuits to develop, secure patents for, and license patented technology to scale within industry (technology transfer). This adds to a running list of commonly reported examples of industry-academia partnerships, which we use to define “industry-academia partnerships”: 1) industry funding for research, engagement/networking events, and training on topics of interest that might not align with government-sponsored research topics, 2) academic consulting to provide subject matter expertise, ethical review, etc., 3) entrepreneurial endeavors (e.g. startups, incubators, accelerators, etc.), 4) public health activities (e.g. Facebook and Carnegie Mellon researchers to address the COVID-19 pandemic), 5) creating industry employment pipelines for STEM students, and 6) faculty pathways for career transition into industry leadership roles, which can be an effective strategy to overcome issues related to STEM workplace inequity.(4)

Industry-academia partnerships have become a paradigm of and pathway to success for STEM faculty. Take, for example, Dr. Deborah Kilpatrick, an AWIS member since 1997 and CEO of Evidation Health, who shared in an interview in AWIS Magazine that when she received her PhD in 1996, she was among the first 15 women to ever get a PhD in mechanical engineering from Georgia Tech.(5) She shared several points about the importance of partnerships in the future of STEM; “Make partnerships a priority: this is probably the most dramatic change I’ve observed in startup “behaviors” over the last decade, and I don’t see it changing. The complexities and interactions of technology across domain boundaries mean that partnerships are required to tackle the really big problems,” she stated. Dr. Kilpatrick’s advice resonates with the view presented here on the importance of smart and trusted collaboration between academic scientists and industry to move science forward and foster a culture of science translation within and outside of academia. In fact, her company, Evidation Health, routinely collaborates with academic scientists to leverage technology to capture, quantify, and analyze human behavior data in the context of human health.(6)

Although, academic scientists in STEM have embraced the new culture and importance of industry-academia partnerships, some have encountered significant challenges in this endeavor.(7) Challenges include limited research funding by federal sponsors like the NIH as well as finding the right tools and resources to develop novel healthcare and biological interventions while simultaneously determining how these interventions can be translated or implemented into practice.(8)

Although industry-academia partnerships can be celebrated as a successful paradigm and pathway to success for academic scientists in the 21st century and beyond, some studies have exposed a gender gap in industry-academia partnerships, rendering those like Dr. Kilpatrick as likely the exception versus the norm.(9,10) From an intersectionality lens, female STEM scientists from academia, especially those of color, that are collaborating, challenging, or working with industry encounter significant hurdles and biases in the workplace. For example, a notable STEM researcher, Dr. Timnit Gebru, specializes in identifying and discussing issues, like gender bias, within technological systems (e.g., systems run by artificial intelligence algorithms).(11) Given the impact of her academic work, Dr. Gebru collaborated with Google as an employee accustomed to academic culture to later encounter "bias and gaslighting," resulting in the end of her employment with Google.(12)

Some studies have examined the benefits and costs of university-industry research collaboration showed that males academics are significantly more likely (64%) than females to collaborate with industry partners and suggested that for this reason female academics may be disadvantaged (when considering prestige or visibility) in their pursuits to collaborate outside academia.(1) Another study found that although female academic scientists have somewhat more collaborators on average than do their male counterparts, the nature collaboration strategies differed; men were more likely to use "instrumental" and "experience" collaboration strategies than women.(13) These findings suggest that it is not just the frequency or rate of collaboration between industry and academia that matters for success, but rather the nature of those collaborations to render or predict certain career trajectories and/or outcomes.

In addition, the University of Houston's Center for ADVANCING Faculty Success (AFS) also this same gender disparity in industry funding for academic STEM researchers within their institution.(14) Although results from this institutional-level assessment was not published in peer-reviewed literature, in a private email one researcher at the AFS was kind enough to look into offering to share their raw data directly in support of this proposed project, if needed. The AFS mentioned that, "No one tracks the numbers nationally, and not all universities report a gender disparity," and thus highlighting the need for this gender analysis gap to be fully realized through a synthesis and qualitative exploration and examination of the literature.(14)
Thus, the purpose of this systematic review was to identify, define, and understand present themes at the intersection of gender and gender intersectionality in industry-academia partnerships in STEM.

Definitions

- **INDUSTRY-ACADEMIA PARTNERSHIP**: Engagement between academics and industry personnel for purposes of providing funding or sponsorship, commercializing technology or applied research, co-authoring papers, providing formal paid consulting, and other pursuing a growing range of commercial and non-commercial developments. Synonymous terms include "university-industry collaboration" and "industry-academia collaboration."

- **GENDER**: Social assumptions assigned to individuals and groups of people or affirmations about oneself in relation to their assignment to assumed biological sex.
- **INTERSECTIONALITY**: A conceptual recognition that personal, group and social identity is a multi-faceted phenomenon that integrates single and integrating identity dimensions such as sex, ethnicity, nationality, skin color, country of origin, etc., at the person and group level. Such recognition is contextual. These identity dimensions, prima facie or otherwise, can socially locate individuals voluntarily and involuntarily leading to biased attitudes and outcomes, either for or against.(15)
- **RESEARCH CENTER**: An entity within or outside of a college, school, or university that is dedicated to or specialized in a specific discipline or practice to provide or offer research, teaching, and service to both the academic and the business communities. Synonymous terms may include "research institute" or "research organization."(16)
- **ACADEMIC DEPARTMENT**: any department, program, unit, or any other administrative subdivision of an institution of higher education that 1) directly administers or supervises post-baccalaureate instruction in a specific discipline; and 2) has the authority to award academic course credit acceptable to meet degree requirements at an institution of higher education.(17)

Methodology

Literature Search

Searches were conducted in relevant electronic databases and peer-reviewed journals using key terms searched included were industry-academia, industry, academia, technology transfer, partnership, collaboration, gender, race, and ethnicity. The literature search comprised of three phases. In the first phase, to capture literature published in the 21st century, peer-reviewed, empirical studies published between 2000 and February 2022 were searched in five electronic publishers and/or databases: Google Scholar, ProQuest/Sociological Abstracts, ProQuest/GenderWatch, and JSTOR. Searches conducted in Google Scholar led to the identification of specific journals of relevance: Journal of Industry-University Collaboration, Industry and Higher Education, Journal of Business Venturing, and Journal of Management Studies. Therefore, in the second phase, searches were also conducted in those four journals. Relevant journals were also identified through prior VVS work: Journal of Technology Transfer; Research Policy; Scientometrics; Higher Education; Minerva; Industrial and Corporate Change; International Management and Entrepreneurship Journal; Technovation; Oxford Review of Economic Policy; Academy of Management Perspective; Sociology Compass; and Gender, Work, & Organization. (15) For the third phase, searches were also conducted in these twelve journals.

Inclusion/Exclusion Criteria

Empirical studies were included in the initial analyses if they examined the role, presence, and/or influence of gender and/or gender intersectionality in topics related to industry-academia partnerships or collaborations. Further, studies showing a quantitative approach without indication of qualitative explanations, studies misaligned with the research topic, and relevant studies not published in English language were excluded from final analyses.

Meta-Syntheses and Thematic Analysis of Key Findings

Meta-syntheses and thematic analyses were conducted using both NVivo and Microsoft Excel. Specifically, standard thematic analyses were conducted using inductive data coding methods (to quantify agreement with known themes and number of quotations falling into new theme categories) and deductive data coding (to identify and develop new categorical and actionable themes) in Microsoft Excel, using constant comparative analysis in accordance with the grounded theory approach.(18)

Principal Findings

Article Selection

Searches conducted in Google Scholar, ProQuest/Sociological Abstracts, ProQuest/GenderWatch, and JSTOR led to four papers that preliminarily met the study inclusion criteria (see Figure 1 in Appendix). Searches conducted in Journal of Industry-University Collaboration, Industry and Higher Education, Journal of Business Venturing, and Journal of Management Studies led to the selection of zero abstracts that met the study inclusion criteria (see Figure 2 in Appendix). A total of 29 articles were selected for inclusion from the Journal of Technology Transfer; Research Policy; Scientometrics; Higher Education; Minerva; Industrial and Corporate Change; International Management and Entrepreneurship Journal; Technovation; Oxford Review of Economic Policy; Academy of Management Perspective; Sociology Compass; and Gender, Work, & Organization (see Figures 3-5 in Appendix). Following a closer assessment of the 33 articles selected for inclusion, 13 were excluded due to ambiguity around or thin relevance to industry-academia collaboration, gender focus, and/or lack of empirical investigation.

Overview

A total of 20 studies published between 2006-2021 were included in the final qualitative analysis (see Table 1 in Appendix).(19-38) Countries of institutions in which studies were conducted (some overlapping due to multiple authors on a single paper from different institutions) included Canada (n= 1), USA (n= 8), UK (n= 4), Spain (n= 2), Italy (n= 3), India (n=1), Denmark (n=1), Netherlands (n=2), China (n=1), Hungary (n= 1), Sweden (n= 1), Taiwan (n=1), and Italy (n=3). Studies included quantitative surveys of individuals/groups or collaborations/studies (n= 17), case studies (n= 1), qualitative interviews (n= 1), and qualitative assessments of "discoveries" (n= 1). Data sources reported across all studies included faculty and scientists (academic-affiliated survey or other social science research participants), public patent registries, peer-reviewed publications, and research program data. Across all studies there were a total of 52,144 individual observations across the following 12 scientific disciplines:

Agriculture	Earth and atmospheric science
Biology	Electrical engineering
Chemistry	Materials engineering
Chemical engineering	Mathematics
Civil engineering	Mechanical engineering
Computer science	Physics

Meta-Synthesis of Research Questions

The following four themes were determined upon assessing overarching research questions posed across all studies (n= 20):

- Effect of gender on industry interaction (n= 5)
- Effect of individual-level factors on industry interaction (n= 5)

- Effect of industry collaboration on academic on performance or market value (n= 7)
- Impact of institutional factors on patent licensing or technology transfer (n= 3)

Assessment of Gender and Intersectionality

Across all studies, the following sociodemographic, explanatory, or independent variables were assessed:

- Gender (n= 20, binary male/female)
- Age (n= 11)
- Race/ethnicity (n= 2)
- Marital status (n= 1)
- Parental status (n= 2)

Very few studies assessed the combined effect of gender and other social demographics on industry-academia collaboration (discussed in Principal Findings below).

Meta-Synthesis of Overarching Themes

The following overarching themes were identified across all studies within the scope of gender and gender intersectionality in industry-academia partnerships:

- **Gender frequency in industry-academia collaboration (n= 9):** The quantification of gender within collaborative research and/or other engagements between industry and academic institutions and/or representatives.
- **Impact of affiliation with university research centers (versus traditional academic departments; n= 5):** Qualifiable or quantifiable impact(s) of belonging to a research center versus an academic department on the occurrence of industry-academia collaborations.
- **Impact of individual-level factors and motivations (n= 6):** Qualifiable or quantifiable person-level (versus group-level) factors that influence the occurrence of industry-academia collaborations.
- **Impact of scientific discipline on industry-academia collaboration (n= 7):** Qualifiable or quantifiable impact(s) of individuals' chosen scientific discipline(s) on the occurrence of industry-academia collaborations.
- **Impact of industry-academia collaboration on scientific production (n= 1):** Relationship between industry-academia collaborations on scientific productivity.
- **Impact of university-industry collaboration on productivity (n= 10):** Qualifiable or quantifiable impact(s) or measures of performance and output of deliverables upon the occurrence of industry-academia collaborations.

Sub-themes were identified within each overarching theme and thus provide an illuminating overview of knowledge and knowledge gaps relative to the Research Question.

Meta-Synthesis of Sub-Themes

The following sub-themes were identified within the overarching theme of "**gender frequency in industry-academia collaboration**":

- Males collaborate more often than females (n= 5)
  - Females engage in activities that require a lower level of time, effort, and resource commitment and thus lower scientific value (n= 1)
  - Negative female experiences in male-dominated workplace culture (n= 1)

- No significant relationship between male gender and time spent working with industry researchers (n= 1)
- Women engaged in wider scientific disciplines have more industry engagement (n= 1)

The following sub-themes were identified within the overarching theme of "**impact of affiliation with university research centers (versus traditional academic departments**"):

- Negative effect observed for industrial activities among females compared to males (n= 1)
- Positive effect observed for commercial activity among females (n= 2)
- Positive effect observed for male status and co-authorship with industry (n= 1)
- Positive effect observed in specific scientific disciplines (n= 1)

The following sub-themes were identified within the overarching theme of "**impact of individual-level factors and motivations**":

- Effect of age or age range (n= 1)
- Effect of social capital or networking ties (n= 1)
- Perception that objective merits matter more than gender (n= 1)
- Positive effect of senior faculty status (n= 2)
- Positive effect on patent commercialization (n= 1)

The following sub-themes were identified within the overarching theme of "**impact of scientific discipline on industry-academia collaboration**":

- Faculty in biology, mathematics, physics, and earth and atmospheric sciences are less likely to engage with industry (n= 1)
- Faculty in chemistry and computer sciences are more likely to engage with industry (n= 1)
- Faculty in engineering are more likely to engage with industry (n= 3)
- Faculty in health sciences are more likely to contract with industry (n= 2)

The following sub-themes were identified within the overarching theme of "**impact of scientific production on industry-academia collaboration**":

- Positive relationship between scientific production and number of contracts (n=1)

The following sub-themes were identified within the overarching theme of "**impact of university-industry collaboration on academic productivity**":

- Effect on overall collaboration
    - Being female and married with children does not influence number of collaborators (n= 1)
    - Decreased effect of male or female gender and increasing age on number of collaborators (n=2)
- Positive effect on employability (n= 1)
    - Positive effect of male gender and placing graduate students in industry jobs (n= 1)
- Positive effect on knowledge transfer or consulting (n= 1)
    - No effect observed when controlling for male or female gender (n= 1)
    - Positive effect observed for younger age (n= 1)
    - Positive effect of male gender (n= 6)
- Positive effect on number of publications or citations (n= 1)
    - No effect observed when controlling for male or female gender (n= 1)

  - Positive effect observed for male gender (n= 2)
  - Positive effect or correlation observed for ethnicity and location of research institution (n= 1)
  - Positive relationship between project leader gender and age (n= 1)
- Positive effect on patenting and patent commercialization (n= 3)
  - No effect observed when controlling for male or female gender (n= 1)
  - Positive effect observed for male gender (n= 3)
  - Positive effect observed for older age (n= 1)
  - Positive effect or correlation observed for ethnicity and location of research institution (n= 1)
- Positive effect on research, innovation, and invention value (n= 3)
  - Lower access to or exclusion from commercial resources among women by their mentors or senior faculty (n= 1)
  - No effect observed when controlling for male or female gender (n= 2)
- Positive effect on teaching and learning (n= 1)

Discussions: Limitations and Recommendations

Limitations

Limitations were noted and observed across several studies regarding the lack of generalizability. For instance, two studies mentioned that their results may only be generalizable to regions that host innovative or elite science-based industries or institutions. Six studies noted that their samples were drawn from a single sample or cross-section in time and one study noted that their research was conducted at the research institute or center (versus university) level, thus also limiting the generalizability of their findings.

Other limitations centered on effects stemming from the general nature of academic collaboration with industry. Two studies noted that faculty respondents may under-report backdoor technology transfer or industry collaboration, given the sensitive nature of industry collaboration. Also, one study noted not accounting for preexisting incentives within the system to interact with industry. Another noted that systematic differences may exist between industry collaborative versus non-collaborative scientists which may have manifested in the study findings. Lastly, one study noted that industry collaboration was not randomly assigned to observe a comparable effect among institutions.

Studies also noted limitations that can be attributed solely to academic settings. One study not that their observations were limited to an academic system that is less dependent on private income, which may not be the case for academia institutions engaged with industry. Another study measured only one form of scholarly impact, foregoing measures of other types of impact that may be considered as valuable among industry collaborators. Lastly, three studies noted sampling from academic institutions classified as "Research Extensive" universities, a term defined by the 2002 Carnegie Classification that has been contested and become obsolete.(39)

Lastly, studies noted limitations with respect to gender observations. One study noted not controlling for gender-level findings that may be explained by scientific discipline. Another noted that the study lacks information on male and female academics' domestic responsibilities that may cause career breaks, which may have affected their observations on gender and industry-academia collaboration. Lastly, two studies noted the likelihood of missing contextual data relevant to gender that may explain their findings.

Recommendations

Recommendations for further exploration and incentivization at the system-level were extrapolated across several studies. First, future work should consider and support optimal conditions for gender-balanced industry-academia collaboration. In addition, universities should address incentive or baseline support systems to encourage gender-diverse faculty to participate in industry collaboration. These efforts could be augmented by future work that may garner industry perspectives on successful collaboration with academia.

Also, given the limitations noted above, there is room for deeper, more longitudinal analyses to identify any unobserved or otherwise lesser-known effects in the present findings. For instance, future work should consider the effect of industry pressures for secrecy and publication delays on gender and racially/ethnically diverse scientists. Moreover, the field would benefit from deeper analyses on if and how the male-dominated nature of the engineering and physical science industries can or has created barriers to feminine and racially/ethnically diverse individuals in science, as early work suggests that racial diversity can affect collaboration among academics engaged in commercial enterprise.(40)

The present findings align with prior, relevant findings similarly summarized by Bozeman, Fay, and Slade.(41) Early work suggests that industry-academia partnerships are spanned by geographic boundaries and thus industry funding for university research can vary country.(42-43) For instance, early developments from Abramo et al. show a positive relationship between university-industry research collaboration and close geographic proximity between universities and private industry organizations.(44) When observing the impact of university-industry collaboration on academic productivity, the present findings suggest a positive relationship between both ethnicity (white or Caucasian race/ethnicity) and the location of research institution as independent variables and patenting and patent commercialization and number of publications or citations. Future work should examine the combined effect of race/ethnicity and gender on academic productivity within university-industry collaborations.

It would be critical to also explore the role of industry in attracting gender and racially/ethnically diverse PhD candidates seeking to collaborate with industry, especially given the socioeconomically competitive advantages to collaborating with industry amid limited governmental or institutional support.(45-50) This is especially given that prior work suggests that young faculty can be sculpted by their collaboration with industry personnel, allowing their careers to become further molded by and accustomed to the experience.(46) The literature suggests that this may cultivate students' ability to publish early in their careers as well as their ability or likelihood to receive greater opportunities for mentorship and lucrative offers for employment.(47-48)

Regarding certain individual-level factors and motivations (i.e., age or age range, social capital or networking ties, objective merits, faculty status, and intent to commercialize patents), the present findings and other literature support these as both important and potentially rate-limiting factors to general engagement in industry-academia partnerships.(49-51) Other literature outside of the present findings additionally suggest that trust built through previous collaboration with industry, racial diversity, choice of research topics (whether influenced by industry or not), faculty preferences for informal collaboration, and concern about exploitation in industry-academia collaborations are also individual-level factors and motivations to consider.(52-64) Future work should prioritize exploring how these individual-level factors and motivations might exist within industry-academia collaborations that are inclusive or exclusive of gender and racially/ethnically diverse scientists. Doing so would foster the creation and operationalization of institutional policies and pathways to support these scientists' ambitions and/or address their concerns along their career pathways.

Conclusion

Industry-academia partnerships and collaborations continue to grow and evolve across a widening range of scientific disciplines. Therefore, it is important to capture the state of evidence on gender and gender intersectionality in industry-academia partnerships to contextualize the state of both challenges and opportunities for gender and racially/ethnically diverse scientists. Through this contextualization, found within the present findings, it becomes possible to identify equitable policies and practices needed to attract, recruit, and retain a diverse array of STEM faculty and science practitioners.

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References

1. Tartari V, Breschi S. Set them free: scientists’ evaluations of the benefits and costs of university–industry research collaboration. *Ind Corp Change*. 2012 Oct 1;21(5):1117–47.

2. NIH. Financial Conflict of Interest | grants.nih.gov [Internet]. [cited 2020 May 23]. Available from: https://grants.nih.gov/grants/policy/coi/index.htm

3. NIH. PAR-18-530: Academic-Industrial Partnerships for Translation of Technologies for Diagnosis and Treatment (R01 - Clinical Trial Optional) [Internet]. [cited 2020 May 23]. Available from: https://grants.nih.gov/grants/guide/pa-files/PAR-18-530.html

4. Funk C, Parker K. Women and Men in STEM Often at Odds Over Workplace Equity [Internet]. Pew Research Center’s Social & Demographic Trends Project. 2018 [cited 2020 May 23]. Available from: https://www.pewsocialtrends.org/2018/01/09/women-and-men-in-stem-often-at-odds-over-workplace-equity/

5. Hendricks-Sturrup R. AWIS Spotlight on Women Leaders in STEM Deborah Kilpatrick, PhD. 2017;(Spring):1,3,41.

6. Research [Internet]. Evidation. [cited 2020 May 23]. Available from: https://evidation.com/research/

7. Savage N. Industry links boost research output. *Nature*. 2017 Dec 6;552(7683):S11–3.

8. Larkin M. Building successful partnerships between academia and industry [Internet]. *Elsevier Connect*. [cited 2020 May 23]. Available from: https://www.elsevier.com/connect/building-successful-partnerships-between-academia-and-industry

9. Tartari V, Salter A. The engagement gap: Exploring gender differences in University – Industry collaboration activities. *Research Policy*. 2015 Jul 1;44(6):1176–91.

10. Kaymaz K, Eryiğit KY. Determining factors hindering university-industry collaboration: An analysis from the perspective of academicians in the context of entrepreneurial science paradigm. *International Journal of Social Inquiry*. 2011 Jan 1;4(1).

11. Buolamwini, J., Gebru, T. (2018). Gender Shades: Intersectional Accuracy Disparities in Commercial ender Classification. <i>Proceedings of the 1st Conference on Fairness, Accountability and Transparency, in PMLR</i> 81:77-91

12. Hao, K. (2020, December 8). We read the paper that forced Timnit Gebru out of Google. Here’s what it says. *MIT Technology Review*. https://www.technologyreview.com/2020/12/04/1013294/google-ai-ethics-research-paper-forced-out-timnit-gebru/

13. Bozeman B, Gaughan M. How do men and women differ in research collaborations? An analysis of the collaborative motives and strategies of academic researchers. *Research Policy*. 2011 Dec 1;40(10):1393–402.

14. Industry Funding: Closing the Gap for Women Researchers [Internet]. The Big Idea. 2018 [cited 2020 May 23]. Available from: https://research.uh.edu/the-big-idea/university-research-explained/women-researchers-industry-funding/

15. Nelson T. The academic entrepreneurship of women faculty in STEM: A meta-synthesis [Internet]. *ARC Network A STEM Equity Braintrust*. [cited 2022 December 30]. Available from: https://uploads-ssl.webflow.com/60ceadbbd1b31b75588b6cd7/611521b34b95f3a9e15abfdd_Nelson-VVS.pdf

16. Kumar V. The role of university research centers in promoting research. *Journal of the Academy of Marketing Science*. 2017 Jul;45(4):453-8.

17. Academic Department [Internet]. Legal Information Institute. [cited 2020 December 30]. Available from: https://www.law.cornell.edu/definitions/index.php?width=840&height=800&iframe=true&def_id=172d249c4346615f8db5b6b8f7f96058&term_occur=999&term_src=Title:34:Subtitle:B:Chapter:VI:Part:648:Subpart:A:648.1

18. Chun Tie Y, Birks M, Francis K. Grounded theory research: A design framework for novice researchers. *SAGE Open Medicine*. 2019 Jan;7:2050312118822927.

19. Khonde AP, Hebbar S, Sidharth S, Prasad SH, Patil M, Borate N. A study on the significant influence of industry institute collaboration on various factors in engineering institutes in Pune Region. *The International Journal of Business & Management*. 2014 Jun 1;2(6):11.

20. Link AN, Siegel DS, Bozeman B. An empirical analysis of the propensity of academics to engage in informal university technology transfer. *Industrial and Corporate Change*. 2007 Aug 1;16(4):641-55.

21. Murray F, Graham L. Buying science and selling science: Gender differences in the market for commercial science. *Industrial and Corporate Change*. 2007 Aug 1;16(4):657-89.

22. Wu Y, Welch EW, Huang WL. Commercialization of university inventions: Individual and institutional factors affecting licensing of university patents. *Technovation*. 2015 Feb 1;36:12-25.

23. Salimi N, Bekkers R, Frenken K. Does working with industry come at a price? A study of doctoral candidates' performance in collaborative vs. non-collaborative Ph. D. projects. *Technovation*. 2015 Jul 1;41:51-61.

24. Abramo G, D'Angelo CA. Drivers of academic engagement in public–private research collaboration: An empirical study. *The Journal of Technology Transfer*. 2022 Dec;47(6):1861-84.

25. Zhang B, Wang X. Empirical study on influence of university-industry collaboration on research performance and moderating effect of social capital: evidence from engineering academics in China. *Scientometrics*. 2017 Oct;113(1):257-77.

26. Clark BY. Influences and conflicts of federal policies in academic–industrial scientific collaboration. *The Journal of Technology Transfer*. 2011 Oct;36(5):514-45.

27. Landry R, Amara N, Ouimet M. Determinants of knowledge transfer: evidence from Canadian university researchers in natural sciences and engineering. *The Journal of Technology Transfer*. 2007 Dec;32(6):561-92.

28. Novotny A. The heterogeneity of the academic profession: The effect of occupational variables on university scientists' participation in research commercialization. *Minerva*. 2017 Dec;55(4):485-508.

29. Ponomariov B, Craig Boardman P. The effect of informal industry contacts on the time university scientists allocate to collaborative research with industry. *The Journal of Technology Transfer*. 2008 Jun;33(3):301-13.

30. Berger L, Benschop Y, van den Brink M. Practising gender when networking: The case of university–industry innovation projects. *Gender, Work & Organization*. 2015 Nov;22(6):556-78.

31. Gaughan M, Corley EA. Science faculty at US research universities: The impacts of university research center-affiliation and gender on industrial activities. *Technovation*. 2010 Mar 1;30(3):215-22.

32. Tartari V, Breschi S. Set them free: scientists' evaluations of the benefits and costs of university–industry research collaboration. *Industrial and Corporate Change*. 2012 Oct 1;21(5):1117-47.

33. Tartari V, Salter A. The engagement gap: Exploring gender differences in University–Industry collaboration activities. *Research Policy*. 2015 Jul 1;44(6):1176-91.

34. Boardman PC, Ponomariov BL. University researchers working with private companies. *Technovation*. 2009 Feb 1;29(2):142-53.

35. Aguiar-Díaz I, Díaz-Díaz NL, Ballesteros-Rodríguez JL, De Saa-Perez P. University–industry relations and research group production: is there a bidirectional relationship? *Industrial and Corporate Change*. 2016 Aug 1;25(4):611-32.

36. Azagra-Caro JM. What type of faculty member interacts with what type of firm? Some reasons for the delocalisation of university–industry interaction. *Technovation*. 2007 Nov 1;27(11):704-15.

37. Bikard M, Vakili K, Teodoridis F. When collaboration bridges institutions: The impact of university–industry collaboration on academic productivity. *Organization Science*. 2019 Mar;30(2):426-45.

38. Fassio C, Geuna A, Rossi F. Which governance of university–industry interactions increases the value of industrial inventions? *Industrial and Corporate Change*. 2019 Oct 1;28(5):1227-56.

39. Carnegie Doctoral/Research Universities-Extensive [Internet]. The University of Washington. [cited 2020 December 30]. Available from: https://www.washington.edu/tools/universities.html

40. Chang DB, Dozier K. Technology transfer and academic education with a focus on diversity. *The Journal of Technology Transfer*. 1995 Dec;20(3):88-95.

41. Bozeman B, Fay D, Slade CP. Research collaboration in universities and academic entrepreneurship: the-state-of-the-art. *The Journal of Technology Transfer*. 2013 Feb;38(1):1-67.

42. Collins S, Wakoh H. Universities and technology transfer in Japan: Recent reforms in historical perspective. *The Journal of Technology Transfer*. 2000 Jun;25(2):213-22.

43. Gulbrandsen M, Smeby JC. Industry funding and university professors' research performance. *Research Policy*. 2005 Aug 1;34(6):932-50.

44. Abramo G, D'Angelo CA, Di Costa F, Solazzi M. The role of information asymmetry in the market for university–industry research collaboration. *The Journal of Technology Transfer*. 2011 Feb;36(1):84-100.

45. Matt M, Robin S, Wolff S. The influence of public programs on inter-firm R&D collaboration strategies: project-level evidence from EU FP5 and FP6. *The Journal of Technology Transfer*. 2012 Dec;37(6):885-916.

46. Nedeva M, Georghiou L, Halfpenny P. Benefactors or beneficiary—The role of industry in the support of university research equipment. *The Journal of Technology Transfer*. 1999 Aug;24(2):139-

47. Nilsson AS, Rickne A, Bengtsson L. Transfer of academic research: uncovering the grey zone. *The Journal of Technology Transfer*. 2010 Dec;35(6):617-36.

48. D'este P, Perkmann M. Why do academics engage with industry? The entrepreneurial university and individual motivations. *The Journal of Technology Transfer*. 2011 Jun;36(3):316-39.

49. Jankowski JE. Trends in academic research spending, alliances, and commercialization. *The Journal of Technology Transfer*. 1999 Apr;24(1):55-68.

50. National Academy of Engineering. 2003. *The Impact of Academic Research on Industrial Performance*. Washington, DC: The National Academies Press. https://doi.org/10.17226/10805.

51. Aschhoff B, Grimpe C. Localized norms and academics' industry involvement: The moderating role of age on professional imprinting. [cited 2020 December 30]. Available from: https://ftp.zew.de/pub/zew-docs/veranstaltungen/innovationpatenting2011/papers/Grimpe.pdf

52. Bozeman B, Boardman C. Academic faculty in university research centers: neither capitalism's slaves nor teaching fugitives. *The Journal of Higher Education*. 2013 Jan 1;84(1):88-120.

53. Welsh R, Glenna L, Lacy W, Biscotti D. Close enough but not too far: Assessing the effects of university–industry research relationships and the rise of academic capitalism. *Research Policy*. 2008 Dec 1;37(10):1854-64.

54. Bercovitz J, Feldman M. Academic entrepreneurs: Organizational change at the individual level. *Organization Science*. 2008 Feb;19(1):69-89.

55. Haeussler C, Colyvas JA. Breaking the ivory tower: Academic entrepreneurship in the life sciences in UK and Germany. *Research Policy*. 2011 Feb 1;40(1):41-54.

56. Johansson M, Jacob M, Hellström T. The strength of strong ties: University spin-offs and the significance of historical relations. *The Journal of Technology Transfer*. 2005 Jul;30(3):271-86.

57. Bruneel J, d'Este P, Salter A. Investigating the factors that diminish the barriers to university–industry collaboration. *Research Policy*. 2010 Sep 1;39(7):858-68.

58. Chang DB, Dozier K. Technology transfer and academic education with a focus on diversity. *The Journal of Technology Transfer*. 1995 Dec;20(3):88-95.

59. Clark BY. Influences and conflicts of federal policies in academic–industrial scientific collaboration. *The Journal of Technology Transfer*. 2011 Oct;36(5):514-45.

60. Cooper MH. Commercialization of the university and problem choice by academic biological scientists. *Science, Technology, & Human Values*. 2009 Sep;34(5):629-53.

61. Link AN, Siegel DS, Bozeman B. An empirical analysis of the propensity of academics to engage in informal university technology transfer. *Industrial and Corporate Change*. 2007 Aug 1;16(4):641-55.

62. Mendoza P. Academic capitalism and doctoral student socialization: A case study. *The Journal of Higher Education*. 2007 Jan 1;78(1):71-96.

63. Renault CS. Academic capitalism and university incentives for faculty entrepreneurship. *The Journal of Technology Transfer*. 2006 Mar;31(2):227-39.

64. Slaughter S, Campbell T, Holleman M, Morgan E. The "traffic" in graduate students: Graduate students as tokens of exchange between academe and industry. *Science, Technology, & Human Values*. 2002 Apr;27(2):282-312.

Appendix: Figures and Tables

Figure 1. Electronic database search results: Google Scholar, ProQuest/Sociological Abstracts, ProQuest/GenderWatch, and JSTOR

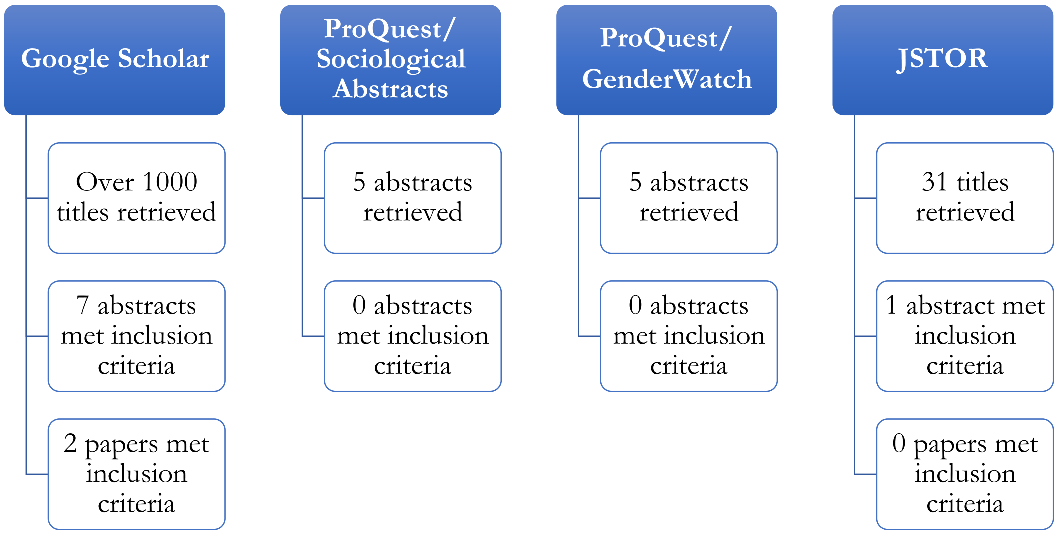

Figure 2. Electronic journal search results: Journal of Industry-University Collaboration, Industry and Higher Education, Journal of Business Venturing, and Journal of Management Studies

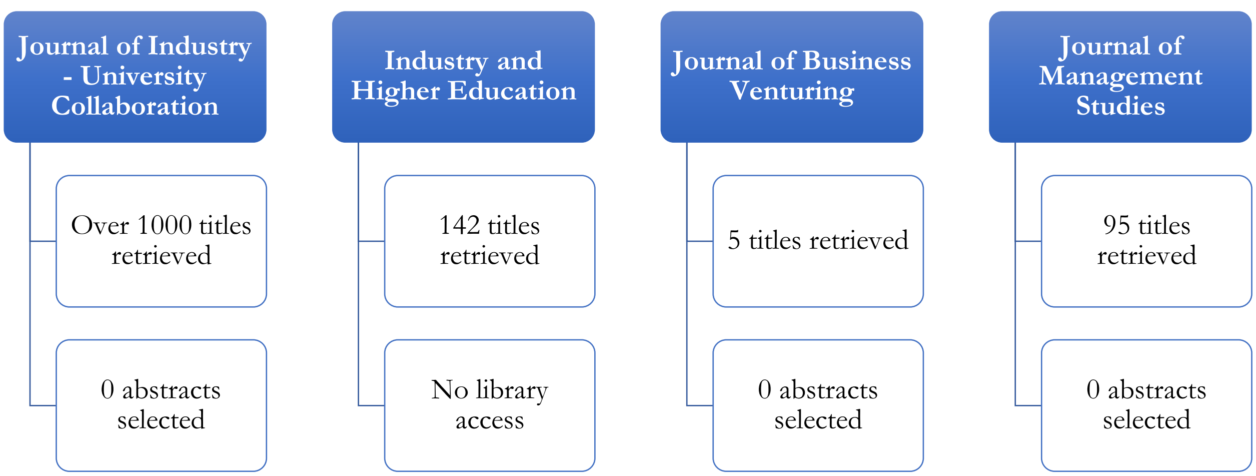

Figure 3. Journal search results: Journal of Technology Transfer, Research Policy, Scientometrics, and Higher Education

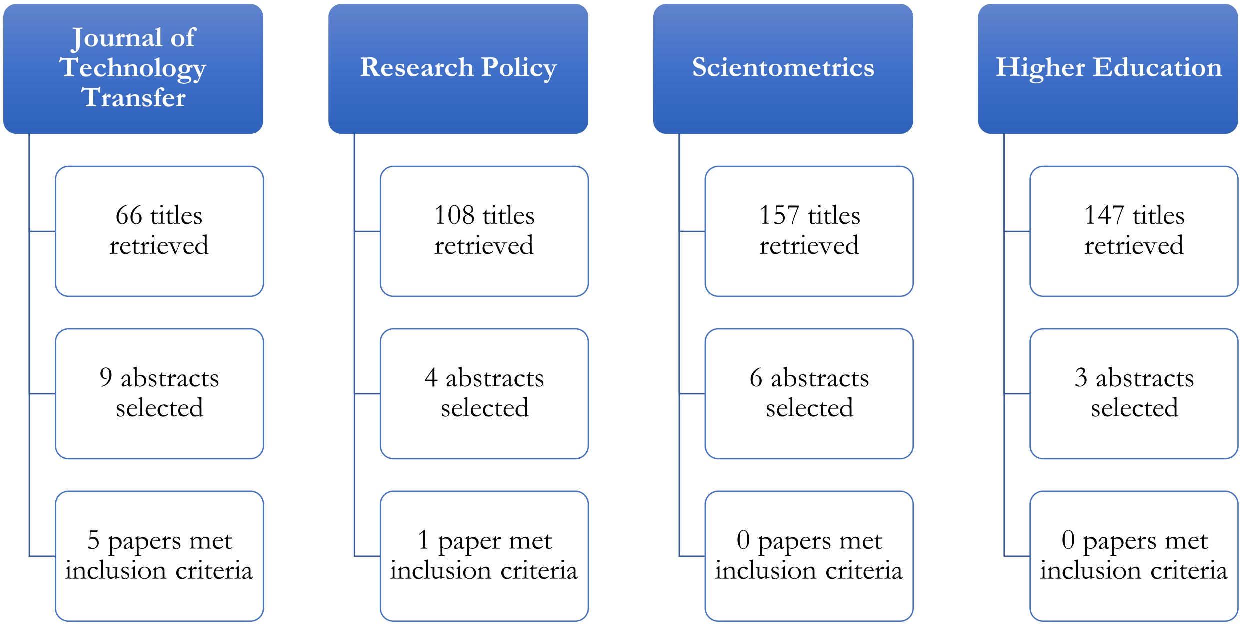

Figure 4. Journal search results: Minerva, Industrial and Corporate Change, International Management and Entrepreneurship Journal, and Technovation

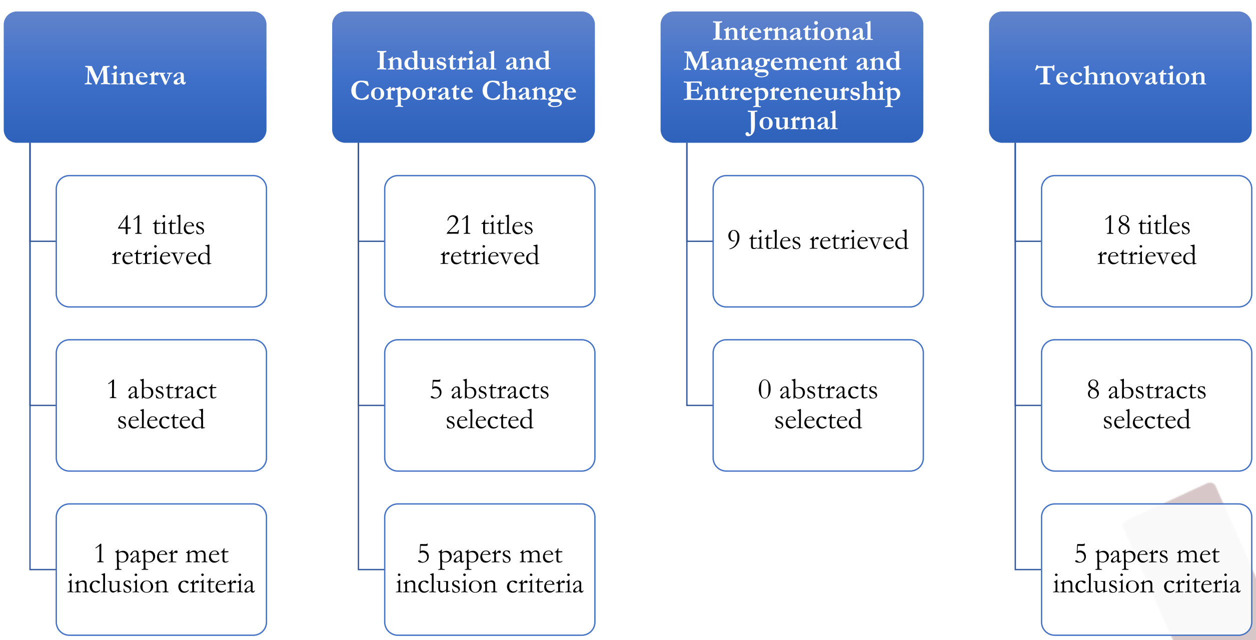

Figure 5. Journal search results: Oxford Review of Economic Policy; Academy of Management Perspective; Sociology Compass; and Gender, Work, & Organization

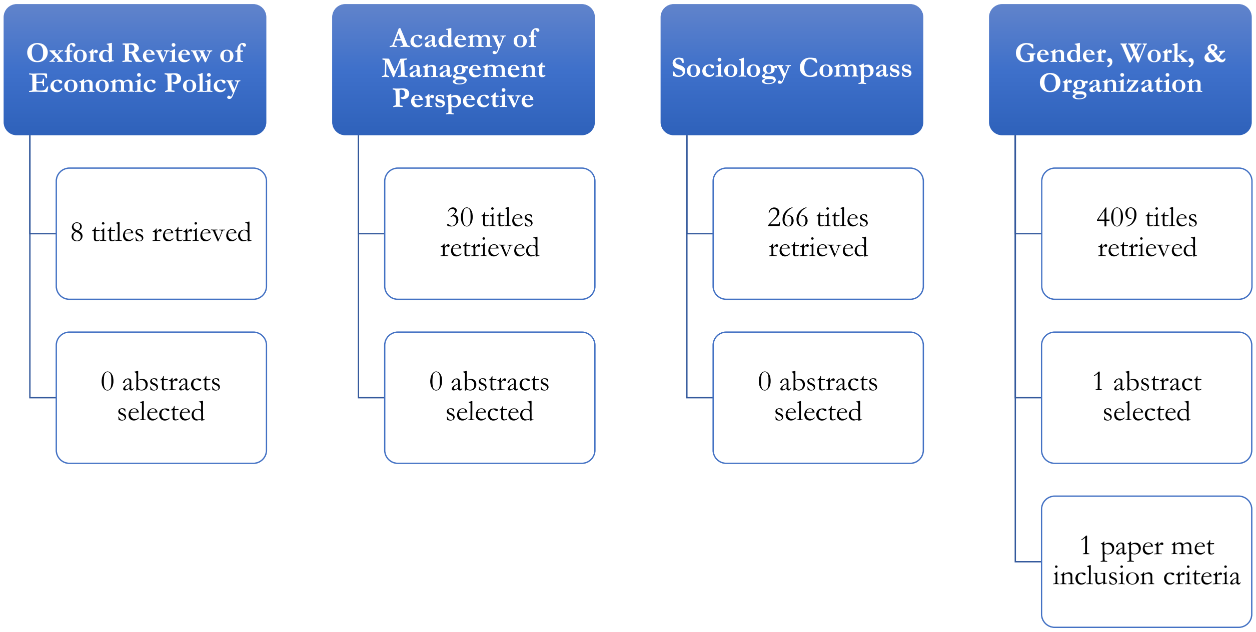

Table 1. Summary of authors, year of publications, and geographic locations of studies

Author	Year	Institution Location(s)	Gender and/or Intersectionality Focus	Research Aim
Abramo and D'Angelo	2022	Europe (Italy)	Assessed gender as a descriptive variable. Assessed age as a descriptive variable, observing the intersectional effect of gender and age range as 1) female professors aged 45 and under and 2) female professors aged 60 and over.	To determine a possible link between research collaboration and performance, many studies have relied simply on the aggregate profile of the department or institution as a proxy of the research quality of the individual scientists.
Bikard, Vakili, and Teodoridis	2019	USA/UK	Assessed outcomes using "share of female authors" and "academia-industry collaboration as independent variables within summary statistics and inferential statistical modeling. No intersectionality focu.	To determine if university-industry collaboration can sometimes foster specialization and boost academic contribution to open science.
Fassio, Geuna, and Rossi	2019	Europe (Sweden, Italy)/UK	Assessed the share/percentage of women who participated in the survey. Study controlled for age and gender.	To evaluate the relative impact of two alternative types of governance of university-industry interactions (personal contracts stipulated with individual academic researchers and institutional contracts stipulated with the university) on the value of collaborative inventions produced by industry researchers.
Novotny	2017	Europe (Hungary)	Assessed the distribution of women within the sample. No intersectionality focus.	To assess the heterogeneity of university scholars by examining the effect of occupational characteristics on research commercialization behavior.
Zhang and Wang	2017	China	Assessed gender and age as descriptive variables.	To explore how university-industry collaboration (UIC) intensity impact academics' research performance and whether the structural and relational social capital, in terms of network ties and tie strength, mediates the relationship

Author	Year	Institution Location(s)	Gender and/or Intersectionality Focus	Research Aim
				between UIC and research performance.
Aguiar-Diaz et al.	2016	Europe (Spain)	Gender was measured as a value of 1 when the leader was a man and 0 when it was a woman. Age was determined by the difference between 2010 and the date from which groups' members began to work informally.	To analyze the effect of university-industry relations (as a possible bi-directional pattern) on the research groups' scientific production at universities.
Wu et al.	2015	USA/Taiwan	Gender of inventor (whether candidate is male) was used as a control factor/covariate only within model estimates to test six distinct hypotheses. No gender subgroup analysis. No intersectionality focus.	Determine how individual and institutional factors influence the likelihood of licensing university patents.
Salimi et al.	2015	Netherlands	Gender of candidate (whether candidate is male) was a considered an independent or explanatory variable. No gender subgroup analysis. Whether candidate is Dutch was a considered an independent or explanatory variable within binary logit regression models assessing publications/patents plus respective citations as dependent variables. No Dutch subgroup analysis. No other subgroup analysis or intersectionality focus.	This study considers university-industry collaboration through joint PhD projects at Eindhoven University of Technology. Purpose is to empirically investigate the effect of industry collaboration (and also Public Research Organizations; PROs) on academic performance in the context of PhD projects. Considers actual differences in performance levels and identifying the determinants of performance differences.
Tartari and Salter	2015	Europe (Denmark)/UK	Assessed the effect of female presence. No intersectionality focus.	To determine if women academics engage less and in different ways than their male colleagues in similar status in collaboration activities with industry.

Author	Year	Institution Location(s)	Gender and/or Intersectionality Focus	Research Aim
Berger, Benschop, and van den Brink	2015	Europe (Netherlands)	Assessed the different ways in which gender was practiced among the participants. No intersectionality focus.	To explore gender in group-level networking practices in university-industry innovation projects through a combination of observations and interviews.
Khonde et al.	2014	India	Gender was captured as male/female. Also observed age range.	Identify whether industry institute collaboration has a significant influence on (in the pune region): 1) research and innovation in engineering institutes, 2) teaching and learning in engineering institutes, 3) employability in engineering institutes, and 4) knowledge transfer in engineering institutes. Also, identify the most signficant method of knowledge transfer between industry and institute. Target population/persons are faculty of engineering institutes who participated in Research Collaboration Projects and other Industry-Institute Partnership Activities.
Tartari and Breschi	2012	Europe (Italy)/UK	Evaluated the effect of gender (male= 1) as an independent variable. Evaluated age as an independent variable. No intersectionality focus.	The aim of this paper is to explore to what extent their decisions are explained by individual evaluations of the expected benefits and costs of collaborations, controlling for personal characteristics, such as age, gender, tenure, and scientific field, and for the institutional environment.

Author	Year	Institution Location(s)	Gender and/or Intersectionality Focus	Research Aim
Gaughan and Corley	2010	USA	Women were oversampled to ensure the ability to make gender-based comparisons. Observed race/ethnicity (Caucasian, Asian, African American, Hispanic, Native American) and age as descriptive/independent variables.	The study focuses on how gender and institutional location within universities influence the pattern of industrial interactions by tenured and tenure-track scientists and engineers working at research extensive universities within the United States. Over half of the professors in the sample work in some capacity with private industry, while 40% are affiliated with a university research center.
Clark	2010	USA	The survey sample was stratified by gender. Control variables included age, marital status, and number of children.	To determine if academics that engage in industrial collaboration have a greater number of academic and total collaborators.
Boardman and Ponomariov	2009	USA	Assessed for effects of gender. Historically Black Colleges and Universities were intentionally excluded from the study sample. Study observed effects based on age and minority status.	To explore and analyze individual-level data measuring relationships between university scientists' behaviors, productivity, and funding sources as well as other characteristics including institutional relations, personal attributes, and scientific values.
Ponomariov and Boardman	2008	USA	Assessed gender and age as descriptive variables.	To explore whether university scientists who engage in networking behaviors with private companies (e.g., information related to the exchange of research) are more likely to engage in collaborative research with industry scientists and devote a greater proportion of their research time to inter-sector research.
Link, Siegal, and Bozeman	2007	USA	Sample was balanced between randomly selected men and	To provide empirical evidence on the extent of and determinants of informal

Author	Year	Institution Location(s)	Gender and/or Intersectionality Focus	Research Aim
			women. Age was assessed as an independent variable.	technology transfer by university faculty.
Murray and Graham	2007	USA	Assessed gender for male/female comparison. Parental status was assessed n descriptive statistics.	The explore the gender gap in commercial science at a single institution.
Azgaro-Caro	2007	Europe (Spain)	Observed age ("senior" if over 40 years of age) and gender in descriptive statistics.	To test the hypothesis that only selected faculty members interact with selected firms.
Landry, Amara, and Ouimet	2006	Canada	Assessed gender as a descriptive/control variable. No intersectionality focus.	To compare the extent of research transfer across research fields and identify determinants of research transfer (transmission and presentation of research results, sitting in on working groups involving users, provision of consulting services, contribution to the development of products or services, involvement in business activities, commercialization of research results) by research field.